A Finger-Ring Antenna for BAN and PAN applications

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1. Introduction

"Body Area Network" or "Personal Area Network" is emerging technology to realize a ubiquitous society. In such a society, easy and seamless but highly secured wireless communication network should be established. Therefore several researchers are challenging to use human-body as a secured transmission line[1], where on-body antenna become an important device. The wristwatch communicator proposed by Itoh et.al. is one of the example[3]. It used 13.8MHz, where the antenna is used as just only an exciter of the human-body, and establishes a high-secured body centric channel mainly using a human-arm. It has been developed successfully; however, human-body must be excited using direct-grounding on the skin because of such low frequency operation, which might cause metal allergy of an operator. In ubiquitous world in the future, from other viewpoint, wristwatch might be too large and should be downsized such as a finger ring.

In this paper, we discuss a possibility of small and wearable antenna applicable to finger-ring size communicator. A modified gate-shape antenna and an inverted F antenna are proposed, and their characteristics are compared using FDTD-simulation. Both have an advantage that the structure can be designed to avoid metal-skin contact.

2. Basic Structure and Characteristics of Finger-Ring Antenna

A configuration of the proposed antenna is shown in Fig.1. They are modified antenna of a gate-shape antenna and an inverted F antenna composed of two strip conductors. A ground-strip is bended to wrap around a human finger, which covers three planes around the finger. The rest is covered with a supporting material such as a plastic material, which can be replaced with a conductive strip without heavy performance degradation. The ground-strip of the antenna is not directly touched to the human body which is floated slightly from the finger-skin to avoid a metallic allergy. Since the original gate-shape antenna has a bi-directional beam pattern, it is suitable characteristics for surface wave excitation along the human body. It resonates when the aperture length L_1+2L_2 is about $\lambda/2$ in principle, and produces the bi-directional beam pattern against the antenna aperture. Inverted-F antenna resonates when the element length L_1+L_2+W is about $\lambda/4$ and the pattern is hemispherical over the ground plane. In this paper, the antennas are designed for 2.45GHz ISM band so that it is applicable to high speed data communication.

Fig.2 shows the reflection characteristics of the proposed antennas, where L_1=24mm, L_2=18mm, w=10mm, h=2mm. Calculated fractional bandwidth (S_{11}<-10dB) of a gate model antenna presented with a solid line is 1.2%. The calculated fractional bandwidth of the inverted F model antenna is 2.1%, which is greater than that of the gate-shaped antenna.

Fig.3(a) and (b) show the radiation pattern of the gate model antenna and inverted-F antenna at the minimum reflection frequency, which is placed is free space. It is assumed that the finger is oriented to the x-axis, where the effect of the finger is not considered. It is confirmed that the gate shape antenna radiates mainly along the x-axis, while the inverted-F antenna has strong radiation also in the y-direction.

3. Characteristic with the hand model by position on the finger

Fig.4 shows an approximate hand-with-arm model, where the antenna is mounted on the forefinger. The length of the palm and arm are denoted as a=b=15mm, c=80mm, d=80mm, *e*=160mm and *f*=200mm, respectively. The parameter *g*=20mm is a popular position for ring-wearing when the origin parameter *g* is set at the bottom of the forefinger. The hand-with-arm model is approximated as a perfectly electric conductor.

Using the model as shown in Fig.4, antenna characteristics are examined in terms of antenna-mounting position. Fig.5 shows the reflection characteristics. The shift of resonance frequencies is within 3% maintaining the matching status. It is not so large and may be tuneable by antenna geometry or some matching circuit.

Fig.6(a) shows a radiation pattern of the gate model antenna mounted on the hand-with-arm model, where the antenna position *g* is chosen as a parameter. When the antenna is at the centre of the forefinger (g=40mm), it radiates bi-direction along the x-axis. When the antenna is at the finger-top (g=60mm), radiation toward the arm increases slightly. As shown in Fig.6(b), the inverted-F antenna has similar change for antenna position, while it maintains the strong radiation toward the y-direction.

Next, we present a brief investigation from the viewpoint of a body-centric communication. Fig.7 shows the E-field distribution on the xy-plane, where the antenna is mounted at *g*=20mm. It is shown that the field excited by the gate-shape antenna is greater than that by the inverted-F antenna along the arm, while strong field of the inverted-F antenna is limited in the positive y-direction. It should be noted that a shadowing effect of the hand is observed in $90<\phi<270$ on the xy-plane.

Fig.8 shows the E-field strength for *g*=20mm as a function of the observation point *x*, where the observation point is 1mm away from the arm. It is normalized by the field at the excitation point. The origin of *x* is set at the bottom of the wrist. The attenuation ratio which is about 2dB per 100mm is common for the both antennas; however, 5dB-improvement using gate-shape antenna is confirmed against the inverted-F antenna. As a result, it can be confirmed that the gate-shape antenna has an advantage in body-centric communication.

4. Conclusion

The characteristics of two types ring-shape antennas were examined using FDTD simulation. Antenna performances around 2.45GHz-ISM band were presented, which was simulated using a hand-with-arm model. It is shown that human-hand does not affect on the input characteristics as long as the antenna is side-mounted on the forefinger. It is also confirmed that the proposed gate-shape antenna has an advantage in body-centric communication such as BAN, while the inverted-F antenna is suitable for PAN application. Bandwidth enchantment is left as a future problem.

ACKNOWLEDGMENT

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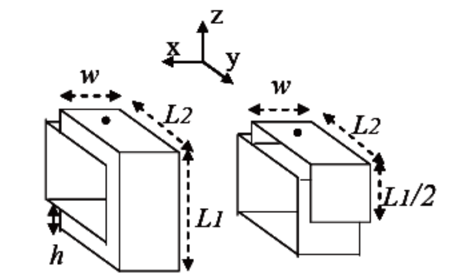


(a) Gate-Model (b) Inverted F-Model

Fig.1 Antenna configuration

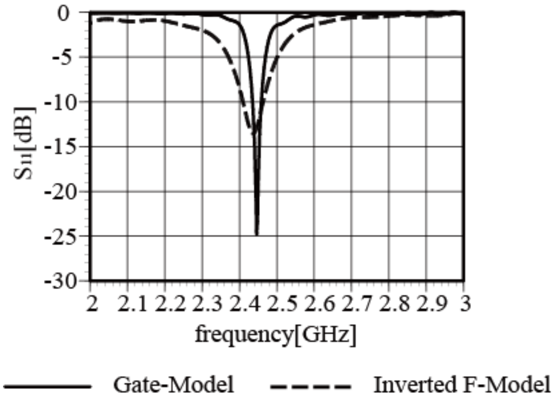


Fig.2 Reflection characteristics

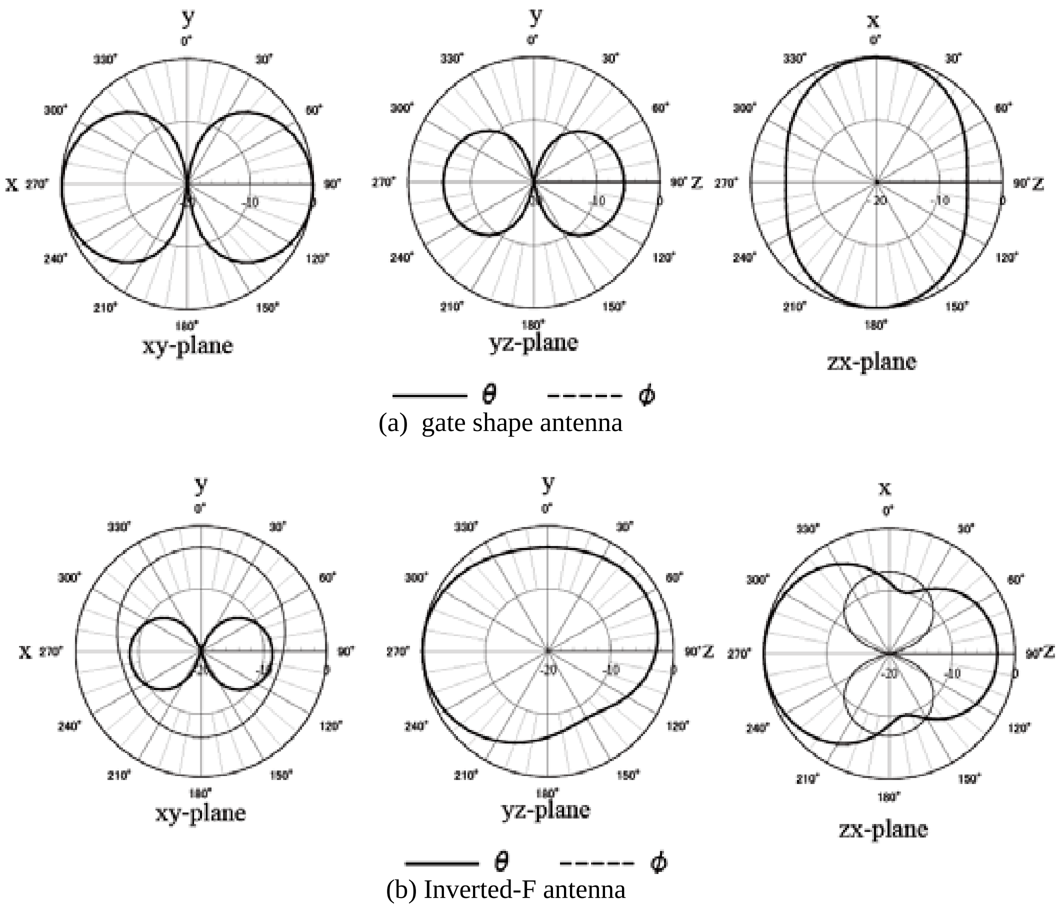


Fig.3 Radiation pattern

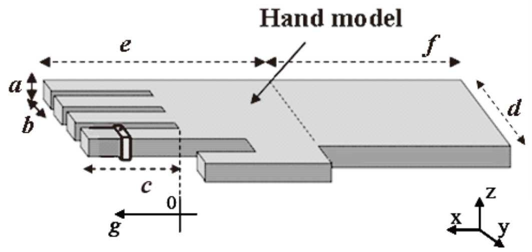


Fig.4 The arm model

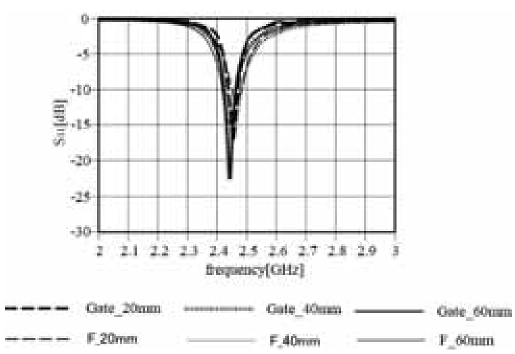
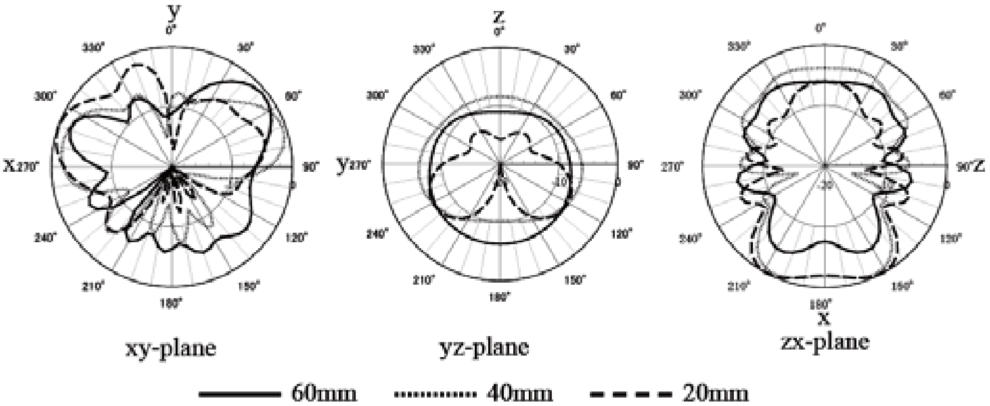
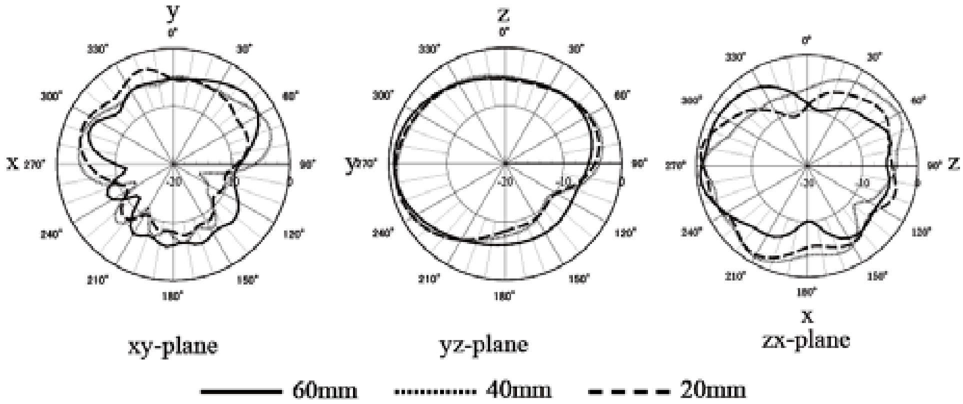


Fig.5 Reflection characteristics with arm model

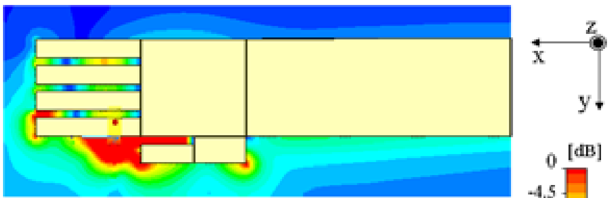


(a) Gate shape antenna

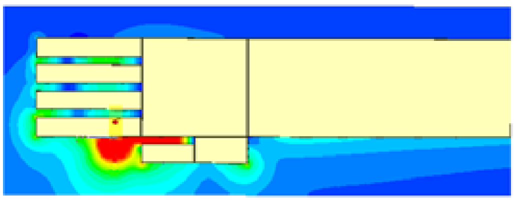


(b)Inverted-F antenna

Fig.6 Radiation Pattern with arm model



(a) E-field (Gate Model)



(b) E-field (Inverted F Model)

Fig.7 E-field (xy-plane)

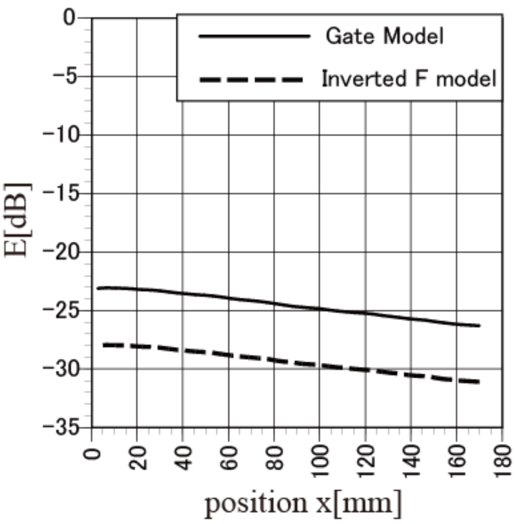


Fig.8 E-field on the arm